



Towards long-term global aerosol optical depth (AOD) records: a consistent retrieval algorithm for MODIS and VIIRS

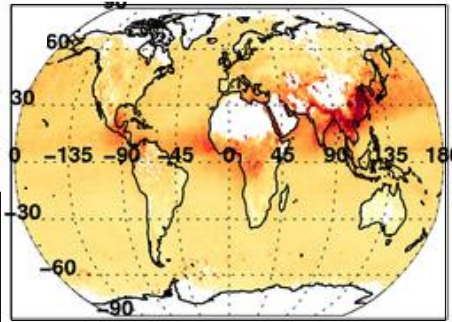
R. C. Levy¹, L.A. Munchak^{2,1}, S. Mattoo^{2,1}, F. Patadia^{3,1}, L. A. Remer⁴, R. E. Holz⁵
¹613/NASA; ²613/SSAI, ³613/GESTAR/MSU, ⁴UMBC/JCET, ⁵SSEC/U. Wisconsin



MODIS



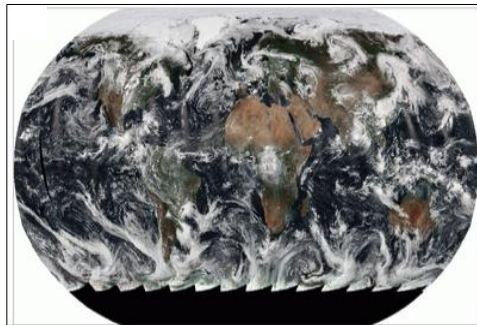
MODIS AOD



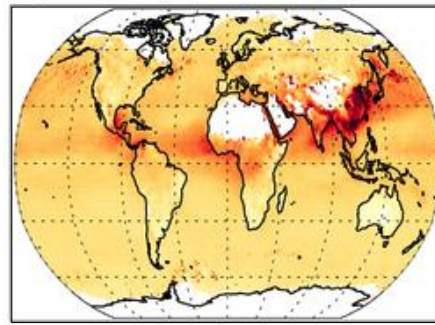
Apply a
consistent
retrieval
algorithm

Apply
consistent
aggregation
and
averaging

VIIRS



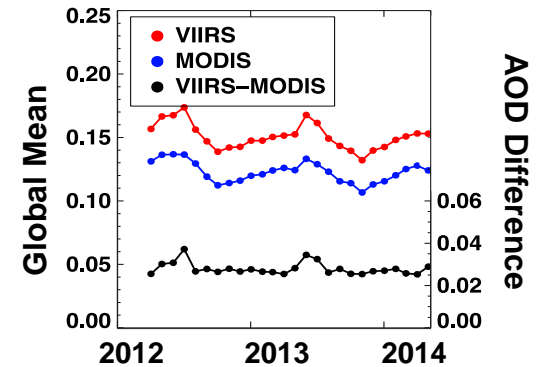
VIIRS AOD



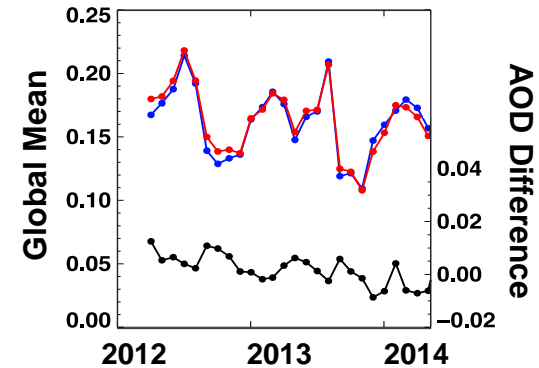
0.55 μm AOD, Spring 2013

-0.05 0.15 0.35 0.55 0.75

OCEAN AOD



LAND AOD



To quantify the global distribution of aerosols, their effects and their changes, we seek a multi-decadal AOD data record. To continue the 15-year AOD record already derived from MODIS, we apply a MODIS-like retrieval algorithm to VIIRS.



Name: Robert C. Levy, NASA/GSFC, Code 613
E-mail: robert.c.levy@nasa.gov
Phone: 301-614-6123



References:

Levy, R.C, L.A. Munchak, S. Mattoo, F. Patadia, L. A. Remer and R. E. Holz (2015): Towards a long-term, global satellite aerosol optical depth record: Applying a consistent aerosol retrieval algorithm to MODIS and VIIRS—observed reflectance, *Atmos. Meas. Tech. Discuss.*, 8, 6877-6947, doi:10.5194/amtd-8-6877-2015.

Data Sources: Top-of-atmosphere reflectance data from MODIS (aboard Aqua) and from VIIRS (aboard Suomi-NPP) were collected during the period March 2012-February 2014. All data were provided as Intermediate File Formatted by the University of Wisconsin. We applied our own MODIS-like, “Dark-Target” aerosol retrieval (Collection 6) to both datasets.

Technical Description of Figures:

Graphics (from left to right): We start with spectral reflectance data from the two sensors (represented with Red-Green-Blue true color imagery), and apply a “consistent” aerosol retrieval algorithm to both. By consistent, we mean a MODIS-like, dark-target retrieval algorithm (first black box) over land and ocean, but accounting for the instrumental/orbital differences between MODIS and VIIRS. After aggregating both datasets the same way (2nd black box), we can create global maps (e.g. 1°x1° latitude/longitude) and global means (integral of grids) of aerosol optical depth (AOD) and other parameters over both land and ocean. In the referenced paper, we compare many statistics to evaluate the similarity of the two datasets during the period March 2012-March 2014. Here, we plot maps of AOD (at 0.55 μm) for the Spring (March-April-May) 2013 season. The two maps look very similar, both in AOD magnitude and spatial distribution. As we continue with the two-year time series of monthly global means, the two datasets track each other very well. While of very similar magnitude, global AOD from VIIRS is biased high by 20% as compared to MODIS. Over land, offsets average near zero, but the difference between the two datasets seems to be trending over time.

Scientific significance, societal relevance, and relationships to future missions: Aerosols are fundamental players in Earth’s radiation budget and climate, and trends in global and regional aerosol properties may influence future climate. To quantify changes in global and regional aerosol properties, we need an accurate and consistent aerosol data record that is both long-term (multi-decadal), and free from artificial jumps or trends. Currently, we have 15 years of derived global aerosol optical depth (AOD) from Moderate-resolution Imaging Spectrometer (MODIS) aboard NASA’s Terra and Aqua satellites. Now that these instruments are aging, we hope to continue the data record with Visible and Infrared Spectrometer (VIIRS) aboard Suomi-NPP and the future JPSS. The MODIS “dark-target” (DT) aerosol retrieval algorithm produces stable, validated, and well-characterized global AOD. However, applying the MODIS DT algorithm, without accounting for the differences between VIIRS and MODIS (e.g., wavelengths, orbits, resolutions, etc), would lead to the kind of jumps and trends that we do not want. Although our consistent algorithm is retrieving AOD data from VIIRS that are very similar to those from MODIS, there are still offsets that require explanation. Differences in calibration, and capabilities for cloud masking, are both examples of obstacles still to overcome. We intend to generate a consistent, long-term aerosol climate data record that can be used in conjunction with models for many climate and air quality applications.

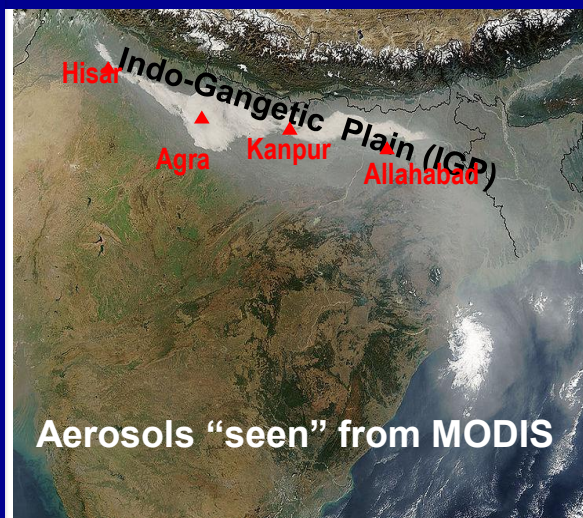
This research began under the NASA program NNH10ZDA001N-NPP (NPP Science Team for Climate Data Records) and continues under NNH13ZDA001N-SNPP (Suomi National Polar-orbiting Partnership (NPP) Science Team).



Aerosol Optical Depth (AOD) is underestimated over South Asia in multiple models

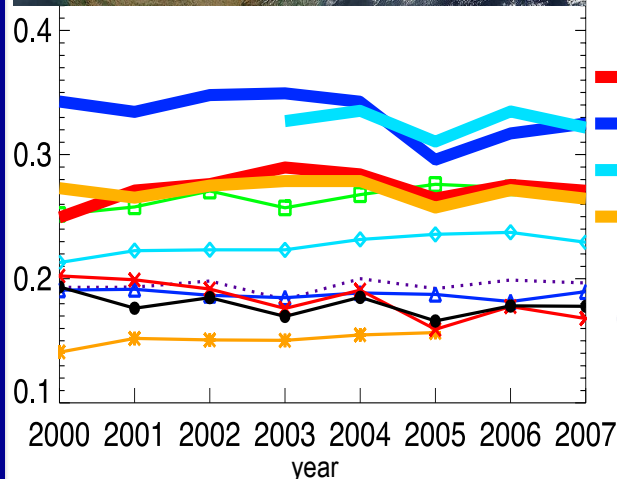
Xiaohua Pan (Code 614), NASA/GSFC, NPP

Annual mean AOD over South Asia 2000-2007 (a)

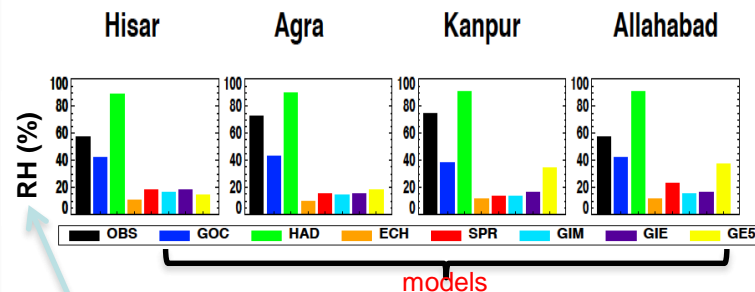


	ave (std)	
ECH	0.151(0.005)	models
GIE	0.194(0.005)	
GIM	0.227(0.008)	
GOC	0.188(0.003)	
HAD	0.265(0.009)	
SPR	0.183(0.015)	
GE5	0.179(0.009)	
SeaW	0.273(0.012)	NASA satellites
MOD-t	0.332(0.018)	
MOD-a	0.326(0.010)	
MISR	0.270(0.008)	

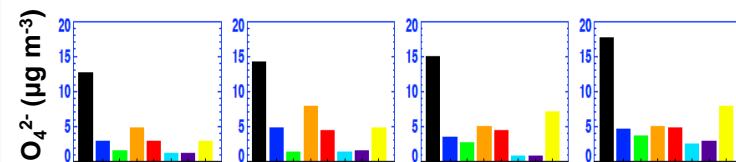
**Common problem:
Modeled AOD too low**



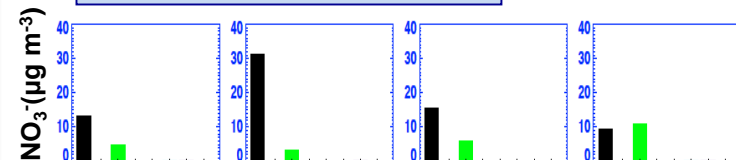
Evaluation at 4 stations Dec 2004 (b)



Relative humidity: OBS~60% but six models~20%



Sulfate: OBS~15 but models < 5



Nitrate: OBS~17, but it is either too low (in three models) or not included (in four models)

Possible causes: errors in meteorology and composition

Six out of seven state-of-the-art global **models consistently underestimate** the **annual mean AOD** by 34% on average compared to **NASA satellite data**. (b) In particular during the **winter time**, most models also largely underestimate the **relative humidity, surface concentrations** of all aerosol species including SO_4^{2-} and NO_3^- at 4 stations along IGP.



Name: Xiaohua Pan, NASA/GSFC, Code 614 and NASA Postdoc Program (NPP)

E-mail: xiaohua.pan@nasa.gov

Phone: 301-614-6002

References:

Pan, X., Chin, M., Gautam, R., Bian, H., Kim, D., Colarco, P. R., Diehl, T. L., Takemura, T., Pozzoli, L., Tsigaridis, K., Bauer, S., and Bellouin, N.: A multi-model evaluation of aerosols over South Asia: common problems and possible causes, *Atmospheric Chemistry and Physics*, 15, 5903-5928, [doi:10.5194/acp-15-5903-2015](https://doi.org/10.5194/acp-15-5903-2015), 2015

Data sources:

We thank the NASA Goddard Earth Science Data and Information Services Center for providing gridded satellite products of **SeaWiFS**, **MISR**, and **MODIS** through their Giovanni website, and thank the ISRO-GBP campaign for making their data available. All data managers and site PIs of those data are gratefully acknowledged. We also thank the AeroCom data management for providing access to the global model output used in this study.

Technical Description of Figures:

Graphics: (a) South Asia, particularly the Indo-Gangetic Plain (IGP) bounded by the towering Himalaya that is conducive to trapping both anthropogenic and dust aerosols, is one of the global hotspots with persistent high AOD routinely observed by satellite remote sensors (e.g. Moderate Resolution Imaging Spectroradiometer or MODIS). However, it has been proven challenging for global models to capture the high AOD. Six out of seven models consistently underestimated AOD by 34% on average compared to NASA satellite data; (b) Several possible causes for these underestimations are suggested: **1.** The wintertime near-surface relative humidity is too low (e.g., about 20% in IGP in six out of seven models, compared to the observed value of > 60%) such that the hygroscopic growth of soluble aerosols and formation of secondary inorganic aerosol, such as nitrate (NO₃) and sulfate (SO₄) are suppressed; **2.** NO₃ is either missing or inadequately accounted for; **3.** Anthropogenic emission, especially from biofuel in winter, is underestimated in the emission datasets. The lack of seasonal variation of emissions amplifies the discrepancies in winter.

Scientific significance, societal relevance, and relationships to future missions:

Atmospheric pollution over South Asia attracts special attention due to its effects on regional climate, water cycle and human health. These effects are potentially growing owing to rising trends of anthropogenic aerosol emissions. Therefore, it is critical to accurately represent aerosol sources, distributions and properties in models over this heavily polluted region in order to project the future climate and air quality changes in South Asia with confidence. Previous studies, however, reported that global models generally underestimated aerosol loading over South Asia, especially over the IGP in winter. We have identified the major discrepancies of seven state-of-the-art global aerosol models in simulating aerosol loading over South Asia. Results from this study suggest clear directions to improve model simulations over this important region, including improving meteorological fields (particularly relative humidity), revising biofuel and agriculture fire emission inventories, and adding/improving nitrate aerosol.